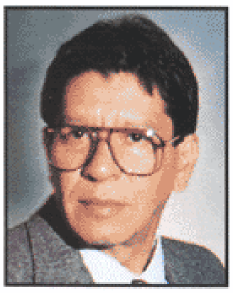
Misalignment and balancing problems at a refinery



by Mariano Sanchez Cabra
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Petroleos Mexicanos' (PEMEX) Tula Refinery is located near Mexico City, Mexico, and employs approximately 4000 people. Its close proximity to Mexico City, and the large amount of petroleum it processes (315,000 barrels/day), make it one of the most important refineries in Mexico. This facility supplies Mexico City with gasoline, aviation fuel, liquid gas, paraffin, diesel and butane.

All Tula Refinery's equipment larger than 1000 horsepower is monitored by Bently Nevada equipment. When the plant was first built in 1976, two Siemens 25 MW turbogenerators monitored by Bently Nevada 7200 Systems were installed. A third turbogenerator was installed in 1988. This 32 MW, Siemens TG-3, four bearing turbogenerator set runs in a clockwise direction as viewed from the steam turbine end (Figure 1). It was initially monitored by a Bently Nevada 7200 System Dual Vibration Monitor with XY probes at each bearing and a system Keyphasor®. It is now being instrumented with a Bently Nevada 3300 Monitoring System. Together, the three turbogenerators supply the plant's power.

After an electrical repair was made on the new generator, high vibration levels were seen during startup using a Bently Nevada ADRE® 3 System. The second startup was recorded, and an analysis of the recorded data showed that Bearings No. 1, 2, 3 and 5 were heavily preloaded. Bearings No. 2 and 3 showed a figure-eight shaped Orbit, as is shown in Figure 2.

The horizontal probe of Bearing No. 2 showed a significant 2X vibration component (Figure 3). Bearing No. 2

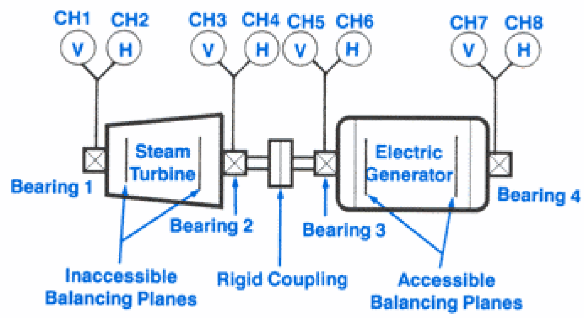

Figure 1
Machine train diagram

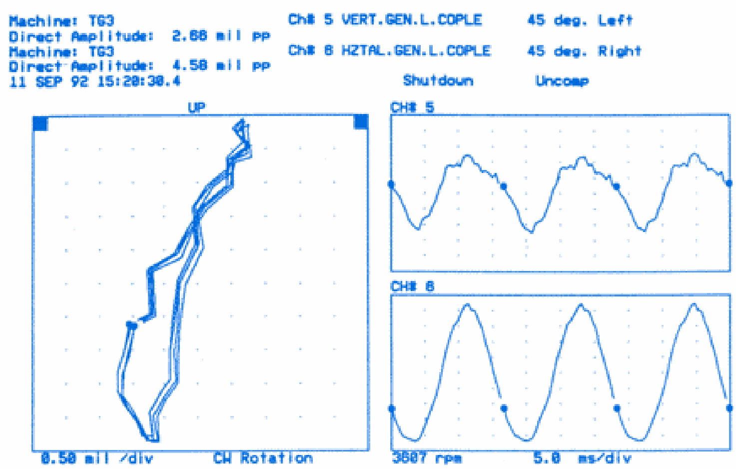

Figure 2
Startup data showing figure-eight shaped Orbit

showed a vibration level of 6 mils at running speed (Figure 4). Bearing No. 4's vertical channel displayed a vibration amplitude of 8.5 mils at the first balance resonance and a residual level of 5.0 mils at running speed (Figure 5).

Analysis of the problem

The presence of the heavily preloaded Orbits (indicated by the figure-eight shape), along with the high vibration levels, clearly indicated that the problem was a combination of severe misalignment and mass imbalance.

Diagnosis

The existence of a vibration component at twice running speed (2X), which has the same amplitude as the component at running speed (1X), might indicate misalignment.

The uncompensated Polar plot (Figure 5) shows a high level of slow roll which indicates the generator's shaft is bowed. This bowed condition is also the cause of the high vibration levels during the first balance resonance. The high vibration levels also show the rotors are operating near the pivotal mode.

The Siemens turbogenerator is of European design and is usually operated at 50 Hz (3000 rpm). Mexico, like the United States, typically operates its turbogenerators at 60 Hz (3600 rpm). Therefore, the generator was operating close to its second mode. There was no access to the turbine's balancing planes; the only access was to the generator.

Due to the time and cost required to disassemble the turbogenerator and bring it to a balancing facility, plant personnel decided to attempt to balance it on-site. Plant personnel took the following factors into consideration in making their decision:

- There was a high level of slow roll at the generator.
- Both the steam turbine and the electrical generator were working close to their pivotal mode.
- No access to the steam turbine's balancing planes made on-site balancing difficult.

The following criteria were defined for the on-site balancing work:

- Weights would be added or removed only at the generator's two balance planes.
- No attempt would be made to balance the generator alone to some minimum standard. Instead, they would attempt to balance both the steam turbine and the electric generator.
- They would try to obtain a balanced response between the vibration level during the pass through to the first balance resonance and the residual vibration level at the running speed for the entire train. ►

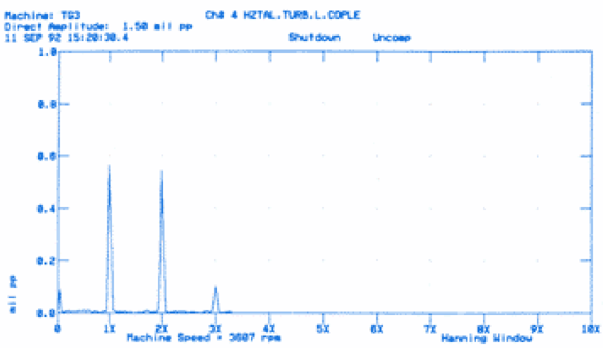

Figure 3
Bearing No. 2 showing 2X vibration component

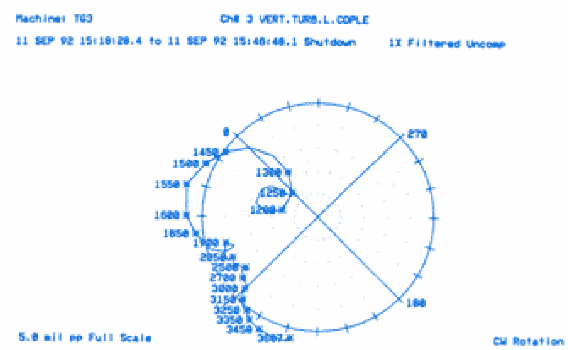

Figure 4
Uncompensated Polar plot of Bearing No. 2

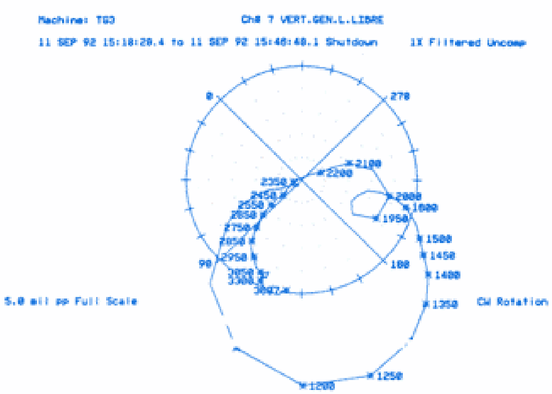

Figure 5
Uncompensated Polar plot of Bearing No. 4

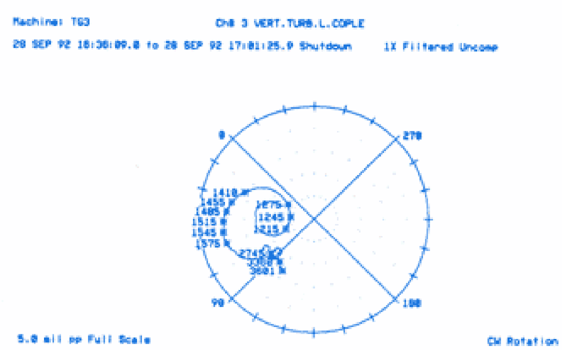

Figure 6
Uncompensated Polar plot of Bearing No. 2 after alignment

A cold alignment was done using a laser beam, and the same equipment was later used to verify the hot alignment behavior. Lateral movement of the steam turbine was identified and was thought to come from the high pressure steam inlet line. A Bently Nevada Transient Data Manager® (TDM) System was used to verify these suspicions. The machine's alignment was modified. However, the origin of the lateral movement of the turbine needs to be determined before the problem can be fully corrected. Plant personnel plan to continue to work to diminish misalignment during the turbogenerator's next shutdown.

After the alignment correction, plant engineers balanced the machine train. Vibration levels were recorded on all channels on both the turbine and the generator during shutdown to generate Polar plots which were necessary to perform balancing calculations. A TDM was used to monitor the on-line behavior of each bearing. TDM data included filtered and unfiltered Orbit/Timebase plots recorded during shutdown and filtered and unfiltered Orbit/Timebase plots recorded at running speed.

Summary

The turbogenerator was put on-line and is working reliably at full load. Vibration levels at every monitored channel decreased at critical speed and at running speed (Figures 6 & 7). Orbit/Timebase plots taken after the alignment correction are more elliptical (Figures 8 & 9), not the figure-eight shape seen previously (Figure 2). Also, the twice running speed component at Bearing No. 2 disappeared (Figure 10).

By using the techniques described above, machine disassembly and removal to a balancing facility was avoided. The repair work would have been extensive, costing $68,000 in U.S. dollars for maintenance costs and lost power generation. ■

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Mr. Mariano Sanchez Cabra has been Chief Engineer of Tula Hidalgo Refinery's Mechanical Maintenance Department for eight years. He previously worked for four years as a Mechanical Engineer in Minatitlan, Veracruz, another PEMEX facility, and has worked for PEMEX since 1977.

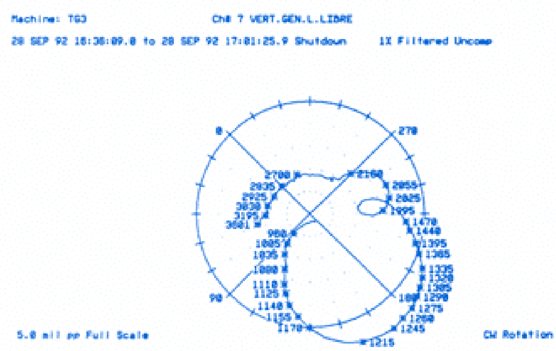

Figure 7
Uncompensated Polar plot of Bearing No. 4 after alignment

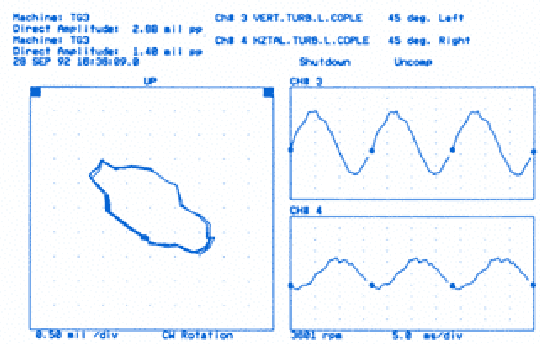

Figure 8
Orbit/Timebase plot of Bearing No. 2 after alignment

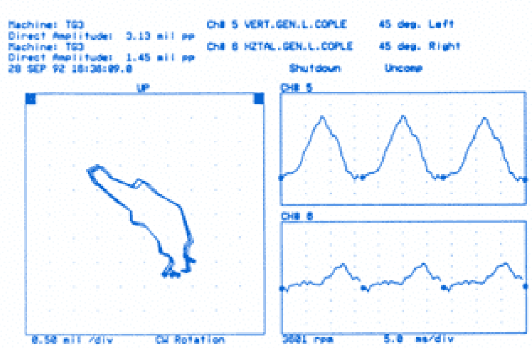

Figure 9
Orbit/Timebase plot after alignment

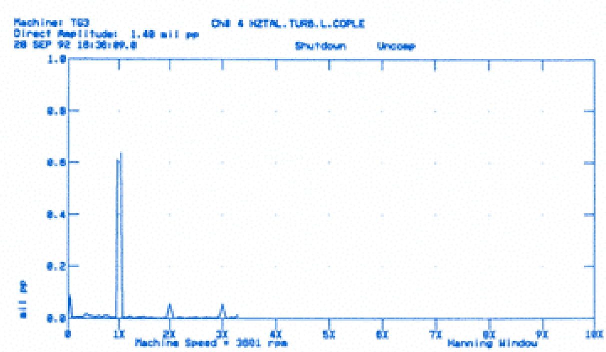

Figure 10
Bearing No. 2 without 2X vibration component